Earth-to-Satellite Quantum Key Distribution with Noise Reduction via Entangled Photon Time Correlation

Completed Technology Project (2017 - 2018)

Project Introduction

The objective of this proposal is to establish a provably secure communication link between ground and low-earth-orbit (LEO). Current communication technologies rely on assumptions about the computational abilities of eavesdroppers (e.g., factoring prime numbers is computationally prohibitive). However, these assumptions have come into question because of recent developments in computational technology such as quantum computers. If such devices were developed and obtained by malicious eavesdroppers, all current communication, from bank transactions to classified government information, would be subject to attack. Quantum key distribution (QKD) is a provably secure method of communication (depending only on the laws of quantum mechanics) that would not be vulnerable to attacks from any amount of computational power. The goal of this project is to develop a QKD protocol that could be used between earth and LEO satellites, securing the integrity of manned and unmanned NASA missions and perhaps setting the stage for a revolution in global secure communication. QKD has been demonstrated in a variety of contexts, including through fiber and through free space. A recent study was able to perform QKD over 143 km of free space through far more atmospheric thickness than exists between the surface of the earth and LEO, proving in principle that such communication is possible. However, this feat was only accomplished on dark nights and at a bit rate of tens of bits per second at best. This example serves to highlight two practical challenges in free-space quantum communication. First, one must have a very high rate single-photon source in order to achieve suitably high data rates after unavoidable losses due to atmospheric effects. Second, one must be able to filter out all other photons received, such as those emanating from the sun. Without meeting these criteria, a practical ground-to-satellite QKD system will not be possible. I propose a modification to the BB84 QKD protocol that will allow for considerable noise cancellation and will function with a high-rate aperiodic entangled photon source such as one operating via spontaneous parametric down conversion. This modification, which I will refer to as BB84+, involves the sender detecting one photon from each entangled pair and classically sharing the time tag of this "idler" photon with the receiver, who in turn uses this information to determine which of the photons he has received did in fact come from the sender and which photons were actually noise. Combined with other measures such as wavelength optimization, such a protocol could be used to reduce noise to a manageable level while performing practical QKD from ground to LEO in daylight. Demonstrating such a system would be a significant step towards ensuring the security of future NASA missions as well as all personal and governmental communications.

Anticipated Benefits

The objective of this proposal is to establish a provably secure communication link between ground and low-earth-orbit (LEO). Quantum key distribution (QKD) is a provably secure method of communication (depending only on the

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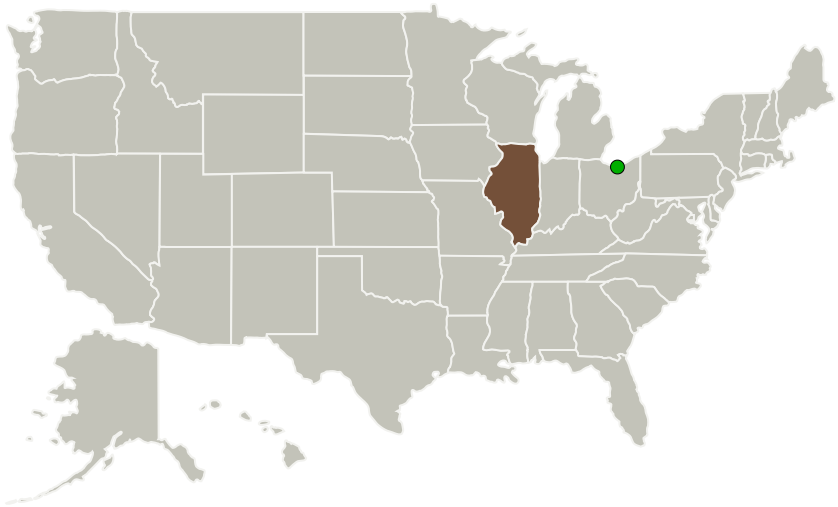
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Lead Organization	Academia	Urbana, Illinois
Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio

Primary U.S. Work Locations
Illinois

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Illinois at Urbana-Champaign

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Paul Kwiat

Co-Investigator:

Dalton W Chaffee

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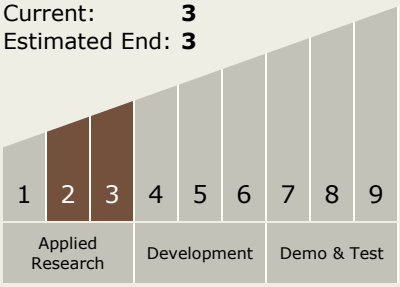
Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - TX05.5 Revolutionary Communications Technologies
    - TX05.5.2 Quantum Communications

Target Destination

Earth